EASON, CLIFTON WAYNE. A Comparison of the Effects of Two Methods of Teaching High School Physics on Understanding of Basic Principles of Physics. (1969) Directed by: Dr. Ernest W. Lee. pp. 60

The purpose of this study was to examine the understanding of basic principles of physics attained by students who were taught by the use of PSSC materials as compared to students who were taught by the use of conventional high school physics materials. The Cooperative Science Test in Physics was used to measure understanding of the basic principles of physics.

The null hypothesis, there is no significant difference between the scores on the Cooperative Science Test in Physics earned by students who have had a one semester course in PSSC physics and the scores earned by students who have had a one semester course in traditional physics, was used. The study covered the period from the beginning of the 1967-68 school year to the end of the first semester.

The control group consisted of the twenty-three students taking traditional physics at Page High School, Greensboro, N. C. The experimental group included the forty-five students taking PSSC physics at Grimsley High School, Greensboro, N. C.

Analysis of covariance was used to compare the change in performance from pre-test to post-test between the two

groups. The analysis showed no significant difference between the two groups. A *t*-test was used to compare the pre- and post-test scores for each group. It was found that both groups made significant improvement at the .01 level of confidence. Thus, it was shown that neither group made significant improvement over the other; rather both groups made comparable improvement.

A COMPARISON OF THE EFFECTS OF TWO METHODS OF TEACHING HIGH SCHOOL PHYSICS ON UNDERSTANDING OF BASIC PRINCIPLES OF PHYSICS

by

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APPROVAL SHEET

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CHAPTER I

INTRODUCTION TO THE STUDY

On October 4, 1957, the first sputnik was orbited and Americans began to ask why America had not been first. The high school curriculum, and high school physics in particular, came under close examination. However, even before this, in the summer of 1956, Dr. Zerrold R. Zacharias and the Physical Science Study Committee, PSSC, had been examining the traditional high school physics course. The result of their study was a plan for a "new" physics course. The PSSC course was to be a course of study in which the major developments of physics, up to the present time, are presented 1) as a logical and integrated whole; and 2) as an intellectual and cultural pursuit which is part of present-day human activity and achievement.[1]

In order to meet these criteria, many of the technical aspects of traditional high school physics were omitted

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[1]Leo E. Klopfer, "The Physics Course of the Physical Science Study Committee -- A View from the Classroom," Harvard Educational Review, XXIX (Winter, 1959), 26.

and a new approach to the study of physics was emphasized. Traditionally, high school physics consists of a number of units, such as heat, light and sound, or mechanics, which contain physical principles, equations, and definitions to be learned and applied by the student. Laboratory experiments are used to confirm the truth of principles and equations.

In contrast, in the PSSC physics course laboratory experiments are used to aid the student in discovering or finding the basic principles and formulas of physics. The entire approach of the PSSC physics course is to lead the student to the discovery of basic principles.

Today, both traditional and PSSC physics are being taught in the high school, but the PSSC course is becoming more and more widely adopted. The purpose of this study was to determine whether the traditional high school physics course or the PSSC physics course gives the student a better understanding of the basic principles of physics.

I. THE PROBLEM

Statement of the problem. The purpose of this study was to examine the understanding of basic principles of physics attained by students who were taught by the use of PSSC materials as compared to students who were taught by the use of conventional high school physics materials.

Hypothesis. There is no significant difference between the scores on the Cooperative Science Test in Physics earned by students who have had a one semester course in PSSC physics and the scores earned by students who have had a one semester course in traditional physics.

Limitations of the study. The study was limited to the forty-five students taking PSSC physics at Grimsley High School and to the twenty-three students taking traditional physics at Page High School. Also, the study was limited to the length of one semester beginning September 21, 1967, and ending February 2, 1968. The study was further limited to the results of change in performance measured by the Cooperative Science Test in Physics.

II. DEFINITIONS OF TERMS

PSSC physics. PSSC physics is a course taught in the junior or senior year of high school in which the texts, films, and laboratory experiments designed by the Physical Science Study Committee are used. The approach of this course is to lead the student to the discovery of basic principles and formulas of physics.

Traditional physics. Traditional physics denotes the conventional physics course taught in the junior or senior year of high school. This approach divides the course into a number of units of study, such as heat, light, mechanics, sound, or electricity. In studying these units the student learns certain physical principles and laws, and, when facilities are available, does laboratory experiments to demonstrate these generalizations.

Sample. The entire population of students taking physics at Grimsley High School and at Page High School in Greensboro, North Carolina, was used in the study. It consisted of the forty-five students taking PSSC physics to be known as the Experimental Group (E) and the twenty-three students enrolled in traditional physics to be referred to as the Control Group (C).

Understanding. In this study the term "understanding" means the ability to comprehend and to apply as measured by the Cooperative Science Test in Physics.

CHAPTER II

REVIEW OF THE LITERATURE

A study released in January 1956 by J. K. Major of the Sloane Physics Laboratory, Yale University, concluded that the introductory physics course at Yale contained (1) too much applied physics, (2) too many topics with no integration, (3) no logical unity, (4) too many examples with not enough development of fundamental principles, (5) a need for intellectualizing. It was suggested that a course similar to the present PSSC course be offered.[2]

In February 1958 in his doctoral dissertation, "A Comparison of the Effectiveness of Two Teaching Techniques on the Ability of College Students to Apply Principles of Physics to New Technical Problems," George Alterman compared the effectiveness of a PSSC-type physics course to a traditional-type physics course to teach students the ability to apply principles of physics to new technical problems.

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[2] J. K. Major, "Introductory Physics in a Program of Directed Studies," American Journal of Physics, XXIV (January, 1956), 30-33.

The experimental and control groups were given four preliminary tests. A t-test analysis showed no initial significant difference between the groups. At the end of one semester the groups were tested for

> a) recall of facts in physics; b) . . . ability to solve mathematical or formula type problems in physics; c) . . . applications of principles of physics to new situations.[3]

A t-test of the means indicated the following results:

> 1) The experimental [PSSC type] method gave significantly better results only with students rating low on preliminary background tests and then solely in the area of application of principles to new situations.
>
> 2) The ability of students to recall facts and principles of physics was highly correlated with the ability to apply principles to new situations as well as with the ability to solve mathematical or formula type problems in physics.
>
> 3) The ability to solve problems was significantly, but not highly, correlated with the ability to apply principles to new situations.[4]

In his article published in Scientific American in April 1958, Walter C. Michels concluded that traditional high school physics texts contain an unnecessary amount of technology and a divisive unit approach to the subject. He

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[3]George Alterman, "A Comparison of the Effectiveness of Two Teaching Techniques on the Ability of College Students to Apply Principles of Physics to New Technical Problems," Dissertation Abstracts, XVIII (February, 1958), 519.

[4]Ibid., pp. 519-520.

also noted that physics must have appeal to other than engineers. He suggested a course whose basis would be an emphasis on basic principles and would give more students a better understanding of the nature of physical science. Dr. Michels pointed out that the course of the Physical Science Study Committee (of which he is a member) did this and had been put together by top scientists, such as Isador I. Rabi and Edward M. Purcell, as well as well-known moviemakers and writers.[5]

In an article published in the American Journal of Physics, September 1958, Dr. Harold P. Knauss of the Massachusetts Institute of Technology and the Physical Science Study Committee, pointed out some features of the Physical Science Study Committee's course.

> The course is designed to arouse interest and to lead students in operating with scientific concepts until they become familiar tools of thought instead of mere verbalizations.[6]

The course emphasizes the relationship of the subject matter to the role of science in everyday life. Laboratory work is an integrated and integral part of the course. Dr. Knauss

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[5]Walter C. Michels, "Teaching of Elementary Physics," Scientific American, CXCVIII (April, 1958), 56-64.

[6]Harold P. Knauss, "Physics for Secondary Schools," American Journal of Physics, XXVI (September, 1958), 379.

stated that the learning toward which the PSSC course was aimed was not tested by conventional tests, but it was hoped students who took the PSSC course would do well on traditional physics tests.

Martin Mann in an October 1958 article published in Popular Science Monthly described the PSSC physics course as emphasizing fundamentals instead of technology and having good laboratory experiments in which something difficult was obtained from something easy. It was stated in the article that a study conducted by the Physical Science Study Committee in 1957 at eight high schools with a population of three hundred physics students concluded that "the more able [students] profited immediately . . . the less able have grown in general understanding."[7] However, it was pointed out that the study was biased in that the schools used in the study were known for having good students. It was also pointed out that the PSSC course is aimed at the upper twenty-five per cent of high school students.[8]

Mr. Darrel W. Tomer, one of the teachers participating

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[7] Martin Mann, "New Way to Teach Modern Science," Popular Science Monthly, CLXXIII (October, 1958), 256.

[8] Ibid., pp. 254-258.

in the development of PSSC physics and one of the first teachers to teach the PSSC course, stated that he believed the PSSC physics course was a higher level course than the traditional high school physics course. He said the PSSC text was more adventuresome and noted that older, simpler ideas, such as simple machines and buoyancy, were omitted in favor of more modern ideas, such as wave and particles concepts.[9]

The Harvard Educational Review devoted most of its 1959 Winter issue to an examination of the PSSC physics course. In an article entitled The PSSC, Dr. Elbert P. Little of the Massachusetts Institute of Technology stated that the traditional physics books were a half century behind the time, new material was added poorly, there was too much material to be taught in one academic year, and there was an overloading of technical ideas with a loss of impact of physical concepts. He noted that the PSSC text has omitted much of the technical material, but also has omitted some physics of considerable significance and interest. The subject matter used in the PSSC text had to meet the

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[9]Darrel W. Tomer, "New Physics Course for High Schools Developed by the Physical Science Study Committee," California Journal of Secondary Education, XXXIII (December, 1958), 492-495.

following criteria:

> 1) to stress the major achievements of physics, such as the great conservation principles; 2) to give insight into the way in which powerful ideas were conceived, nurtured, and sometimes overthrown by even more powerful ideas; 3) to present a unified story in which the interconnections within physics were brought to light; 4) to show physics as a human activity comparable in significance with the humanities, the languages, and other major studies of high school students.[10]

In his article "Math and Physics," Edward P. Rosenbaum found the lack of mathematics in the PSSC physics course disturbing and wondered if "real physics" could be taught without more mathematics.[11]

In "Some Observations of the Work of the PSSC," Alexander Calandra stated that the first volume of the PSSC text was "very colorful, but a rather shaky, pedagogical venture."[12] He noted that volume two was an improvement and that the experiments and movies were good.[13]

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[10] Elbert P. Little, "The PSSC," Harvard Educational Review, XXIX (Winter, 1959), 2.

[11] Edward P. Rosenbaum, "Mathematics and Physics," Harvard Educational Review, XXIX (Winter, 1959), 16-18.

[12] Alexander Calandra, "Some Observations of the Work of the PSSC," Harvard Educational Review, XXIX (Winter, 1959), 21.

[13] Ibid., pp. 20-22.

Leo E. Klopfer, who is a teacher and chairman of the science department at Rham High School, Herbon, Connecticut, stated in his article "The Physics Course of the Physical Science Study Committee -- A View from the Classroom" that the intellectual and cultural value of physics should be more prominently displayed in the PSSC course as "high school students reading the text frequently become enmeshed in the details and must be guided through them to understand science in a larger perspective."[14] Mr. Klopfer felt that in the trial year 1958-59, the aims of the PSSC were met in a rather incomplete way and that there was a need for improvement.[15]

Frederick L. Ferris, Jr., of the Educational Testing Service stated that in trying to answer the question -- is the PSSC course realistic and practical for the average high school student, or is it the product of a group of starry-eyed idealists? -- students of eight high schools were tested for their aptitude, given the PSSC course, and intermittently given six achievement tests throughout the school year. Although the achievement tests showed significant results,

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[14]Klopfer, op. cit., p. 28.

[15]Ibid., pp. 26-28.

the data was biased in that the pre-test showed the students to be well above average. (The mean composite verbal and quantitative score was approximately at the ninety-fifth percentile of the national norms.) It was noted that teachers who had taught the PSSC course reported that they liked it better than the traditional high school physics course.[16] Mr. Ferris also raised the question, "Is the new approach of the PSSC really any better than that which has been used for the past half century?" but left it unanswered.[17]

In April 1961 Charles Nelson Grote published the result of his study on the relative effectiveness of direct-detailed and directed-discovery methods of teaching selected principles of mechanics in the area of physics. Dr. Grote's hypothesis was that there would be no difference in terms of initial learning, retention, and transfer. Six multiple choice power tests were used as criteria. Analysis of variance found that:

1. The direct-detailed group [traditional method] was

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[16]Frederick L. Ferris, Jr., "The Physical Science Study Committee -- Will It Succeed?" <u>Harvard Educational Review</u>, XXIX (Winter, 1959), 29-32.

[17]<u>Ibid</u>.

superior to the directed-discovery [PSSC method] group as measured by the first initial learning test.

2. There was no difference in initial learning at the end of the second lesson or in retention and transfer at the end of the first and sixth week.
3. Lessons taught by the direct-detailed method were only better than lessons taught by the direct-detailed method followed by the directed-discovery method at the end of the first and sixth week.
4. The directed-discovery method had better transfer at the end of one week.
5. Directed-discovery followed by direct-detailed was better than direct-detailed followed by directed-discovery at the end of the six weeks in initial learning and better at the end of one week in retention and transfer.

This research was deficient in that it failed to take into account

> that the relative effects of the methods was dependent, in part, upon interaction of the opposite sexes and/or

ability level of the subjects.[18]

In the school years 1957-58 and 1958-59, Warren L. Hipsher conducted a study to compare the effectiveness of traditional physics to the effectiveness of PSSC physics. Physics students at Will Rogers High School, Tulsa, Oklahoma, constituted the population. The control group consisted of ninety-nine male seniors taught physics by the traditional method in the school year 1957-58. The experimental group consisted of one hundred nine male seniors taught physics by the PSSC method in the school year 1958-59. There were twelve females in the control group and twenty in the experimental group. All were deleted so that sex differences would not be a factor. The students in each group were given the Otis Quick-Scoring Mental Ability test, Form YZ of the General Achievement test in Natural Science, the Engineering and Physical Science Aptitude test, and the North Hatt Scale as pre-tests. Form Z of the Cooperative Physics test was used as the post-test. Both groups were taught by the same teacher in classes of comparable size.

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[18]Charles Nelson Grote, "A Comparison of the Effectiveness of Direct-Detailed and Directed-Discovery Methods of Teaching Selected Principles of Mechanics in the Area of Physics," Dissertation Abstracts, XXI (April, 1961), 3016-3017.

Analysis of covariance showed that after the criterion means were adjusted, the control group mean was 9.5356 points higher than the experimental group mean. The ninety-five per cent confidence limits of difference were 6.1618 and 12.9174. This difference was significant at the .01 level. It was acknowledged that the criterion used was designed to measure achievement in traditional physics and therefore the control group may have had an advantage.[19]

The study by Mr. Hipsher was criticized in an editorial in Science Teacher in February 1962. The editorial pointed out that since the same teacher taught both courses, he could not completely separate one method from the other. It was also noted that PSSC laboratory equipment was not used and that many of the PSSC films were not available at that time.[20]

Walter C. Michels, Francis L. Friedman, Zerrold R. Zacharias, and Frederick Ferris, of the Physical Science Study Committee, noted that the purpose of the PSSC course is

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[19]Warren L. Hipsher, "Study of High Schools Physics Achievement," Science Teacher, XXVIII (October, 1961), 36-37.

[20]"PSSC vs. Conventional Physics," Science Teacher, XXIX (February, 1962), 47-48.

"to represent physics as it is today and to emphasize the development and structure of the subject."[21] It was pointed out that the PSSC course was more idea than practice and therefore must be evaluated by special tests. The difference between the PSSC and traditional course was ascribed to a difference between sets of objectives, rather than to a difference in teaching methods. Although the PSSC physics course was intended to be a part of general education rather than a college preparatory course in physics, a study by Frank Verbrugge found that students who had taken the PSSC course made a higher percentage of A's and B's in college physics than those who had not had the PSSC course.[22]

In an article published in the February 1962 issue of the _Journal of Secondary Education_, Leon M. Lessinger, chief of guidance and psychological services, Grossmont Union High School District, Grossmont, California, described a comparison of PSSC and traditional physics made in his district. Of the six schools in the district, five used the PSSC course. The other used the traditional course and thus acted as a control. PSSC tests and tests in traditional

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[21]_Ibid_., p. 51.

[22]_Ibid_., pp. 51-55.

physics made by teachers were used as achievement tests. All the PSSC physics teachers in California were asked to send data so that norms could be established. The Otis test of general intelligence was given as an aptitude test. Questionnaires and rating sheets were given to pupils, parents, teachers, and administrators. It was concluded that:

1. Pupils who had taken the PSSC course felt they had grown in their understanding of physics, ability to see useful relationships, usefulness of facts, and use of ideas.
2. Parents thought the PSSC program useful.
3. Teachers felt the PSSC course had helped the students who took it learn to think with an understanding of physics as a by-product.
4. PSSC and traditional achievement test scores were comparable for students of similar ability.
5. There was a weakness in the PSSC course in text material, amount of time allotted for laboratory work, and previous pupil preparation in mathematics.

It was generally concluded that the PSSC course was a significant improvement.[23]

In his dissertation at Stanford University, Charles Earling Meridith compared two methods of problem solving in high school physics. The experimental group (PSSC type) developed and studied subject matter close to the energy transformation concept. The control group studied traditional high school physics. The control and experimental groups were matched on criteria of sex, chronological age, score on a pre-test of science problem solving ability (the pre-test showed the two groups to be equivalent). There were twenty-one matched pairs. Teacher bias was eliminated by the use of teaching teams. A *t*-test of the data led Dr. Meridith to reach the following conclusions:

1. The hypothesis,

> The study of principles related to a basic organization concept, "Energy can be transformed from one form to another," is significantly superior to the study of a descriptive survey of physical science as means for developing scientific problem solving ability by students in high school physical science,[24]

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[23]Leon M. Lessinger, "An Evaluation of PSSC Physics," *Journal of Secondary Education*, XXXVII (February, 1962), 97-99.

[24]Charles Earling Meridith, "Development in Problem Solving Skills in High School Physical Science," *Dissertation Abstracts*, XXII (April, 1962), 3550.

was found to be true at the .01 level.

2. The hypothesis,

> The study of principles related to the basic organization concept, "Energy can be transformed from one form to another," is significantly superior to the study of a descriptive survey of physical science as a means for developing knowledge of scientific facts and principles by students in high school physical science,[25]

was rejected.

3. Conceptually related science subject matter content was more suitable for instruction directed toward the goal of gain in problem solving ability than the more usual topical presentation of subject matter.

4. The ability to solve science problems was highly correlated with knowledge of science facts and principles.[26]

In the 1962 Spring issue of School Review, Gilbert C. Finley gave the following figures on the growth of the PSSC physics course:

School Year	Number of Teachers Teaching the PSSC Course	Number of Students Taking the PSSC Course
1958-59	270	11,000
1959-60	560	22,500
after text revision, 1960:		
1960-61	1100	44,000
1961-62 (estimate)	1800	72,000

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[25] Ibid.

[26] Ibid.

Professor Finley pointed out that a comparison of PSSC and traditional physics was not a comparison of teaching methods, but rather of objectives. Traditional physics examinations given PSSC students and PSSC physics examinations given traditional students showed the two groups had studied different courses. It was noted that the College Entrance Examination Board has started giving the two groups different examinations. Results of tests have shown that PSSC physics was not limited to high aptitude students. It was also mentioned that the PSSC physics course has been supported for adoption in several foreign countries.[27]

J. Stanley Marshall described the results of a questionnaire survey of teachers trained to teach PSSC physics by the National Survey Foundation. The survey conducted in Florida in 1960 showed teachers were favorably disposed toward the PSSC course. A repeat of the survey in 1961 found the same results. Marshall also noted that in another study it was found PSSC and non-PSSC students did about equally as well in college physics.[28]

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[27]Gilbert C. Finley, "The Physical Science Study Committee," School Review, LXX (Spring, 1962), 63-81.

[28]J. Stanley Marshall, "Evolving Science Education in Florida," Science Teacher, XXIX (December, 1962), 27-31.

In 1961, seventy-two objectives of high school physics were selected from the PSSC text, traditional books, and a review of the literature of the past ten years. Seventeen objectives were found to be unique to the PSSC course and seventeen unique to the traditional course. Thirty-eight objectives were found to be common to both courses. The objectives unique to the PSSC course were related to such factors as

> the unified nature of the course, the emphasis on basic science rather than on applied science, the reduction in the number of topics covered, and the emphasis on laboratory as the focal point of learning.[29]

The objectives unique to the traditional course were related to such factors as

> consumer knowledge, the scientific method, the application of physics to technology, and laboratory work for the purpose of verifying principles.[30]

Objectives common to both courses were based on "appreciation and interest, teaching techniques, and conceptual development."[31]

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[29]Richard A. Gibboney and others, "Curriculum Components and Organization," Review of Educational Research, XXXIII (June, 1963), 281.

[30]Ibid., pp. 281-292.

[31]Ibid., p. 282.

A questionnaire was sent to a random sample of one hundred PSSC teachers and a random sample of one hundred traditional teachers in order to check agreement with the objectives. Eighty-five per cent of the questionnaires sent to the PSSC teachers were returned. Seventy-six per cent of the questionnaires sent to the traditional physics teachers were returned. The following conclusions were reached:

1. PSSC teachers did show significantly higher agreement with the belief in the unique PSSC objectives than the traditional physics teachers did in 64.5 per cent of the cases, but significantly higher practice in only 47 per cent of the cases. PSSC teachers did not strongly reject the unique objectives of traditional physics when teaching practice was considered.

2. Traditional physics teachers showed a tendency to subscribe to the unique PSSC and joint objectives in addition to the unique traditional objectives.

3. PSSC material adhered to the PSSC objectives and the joint objectives on such factors as (a) presentation of subject matter, (b) learning and teaching methods, on the basis of percentage of these objectives that had rating values above the mean rating value for all objectives.

4. Significant correlations indicated that both PSSC and traditional teachers strongly adhered to the unique objectives of their courses with respect to agreement and practice.

5. PSSC teachers and traditional teachers differed significantly with respect to both agreement and practice in their responses to the 72 objectives.

6. Unique traditional objectives received little attention in PSSC materials (mean rating value 1.20 as compared with an over-all mean of 2.62.)[32]

The minor conclusions of the study which were concerned with the responses of the PSSC and the traditional teachers with respect to size of school, teaching experience, and class size, are of doubtful value because data merely described possible relationships. Moreover, the study was not designed to control relevant variables.[33]

The March 1964 issue of Soviet Education announced that the traditional physics course was being revised. The revised course description compared with the description of the PSSC physics course. In the new course the significance of physics to science, technology, and the cultural life of the society was to be stressed. The course was to be based on present day ideas, principles, and theories of physics and to include more experimentation.[34]

In his dissertation "An Investigation of the Effectiveness of the Program Recommended by the PSSC," Robert Lee Sawyer compared PSSC physics and traditional physics in terms of student achievement on a composite test instrument developed

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[32] Ibid.

[33] Ibid.

[34] Soviet Education, VI (March, 1964), 49-52.

from final exams of both PSSC and traditional physics teachers.

The control and experimental groups were divided in half and each subgroup was taught by an experienced teacher. Each teacher contributed an equal number of test items which were used to make the pre-test and post-test. Analysis of variance showed that the traditional group had a significantly lower mean on the pre-test, but a significantly higher mean on the post-test. On the PSSC portion of the post-test, the PSSC group did significantly better. On the traditional physics portion of the post-test, the traditional group did significantly better. The following conclusions were reached:

1. The groups differed significantly in background as shown by the pre-test.
2. The PSSC program did not fulfill the traditional physics objectives as measured by the non-PSSC portion of the post-test as well as the traditional course did.
3. The traditional physics course did not fulfill the PSSC objectives as measured by the PSSC portion of the post-test.

4. On an examination that combined the objectives of both courses as equally as possible, the traditional physics students scored higher.[35]

In the 1964 Summer issue of the Journal of Experimental Education, Robert W. Heath of the Educational Testing Service at Berkeley published the results of a study comparing traditional and PSSC physics in achievement. The criteria for comparison were the School and College Ability test, form 1A, part 1 -- sentence completion and part 2 -- numerical computation, the Cooperative Physics test, form Z, the PSSC Special Comprehensive Physics Examination, parts 1 and 2, and Thurstone's Concealed Figures test. The Scholastic Aptitude test, SCAT, was given at the beginning of the school year. The other tests were given at the end of the school year. SCAT and the concealed figures test were used as control variables.

All of the random sample of PSSC teachers (31 teachers, 1027 students) invited to participate accepted. Ninety per cent (50 teachers, 2110 students) of the traditional physics teachers accepted. One teacher was dropped from each group

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[35]Robert Lee Sawyer, "An Investigation of the Effectiveness of the Program Recommended by the PSSC," Dissertation Abstracts, XXIV (June, 1964), 5254-5255.

because of improper marking of answer sheets.

A Chi-Square test was used to test the significance of the difference between the distribution of the PSSC sample and the PSSC population. No significant difference was found. A Chi-Square test comparing the distribution of the control sample to the PSSC population found no significant difference.

The traditional physics group scored slightly higher on the Cooperative Physics test. The PSSC group did substantially better on the PSSC examination and had a higher proficiency on the concealed figures test. It was found that the method used to test for significance of the PSSC and traditional groups on the PSSC examination was not legitimate; however, the PSSC group did score significantly better.

Analysis of covariance was used to compare the group means. (See Appendixes A and B for statistical summary.) The following conclusions were reached:

1. PSSC students did significantly better on the PSSC examination.
2. Traditional physics students had a slightly higher average score on the traditional test (Cooperative Physics test, form Z).

3. PSSC classes acquired cognitive style measured by the concealed figures test to a greater degree than the traditional classes.

4. Cognitive style was related to the achievement scores of the PSSC classes on both criterion tests. In the control group the use of objects in a new way is not related to achievement on the criterion tests.

It was generally concluded that the two courses are different in content.[36]

The purpose of Paul Jackson Cowan's research was to

> develop new autoinstructional materials using content, methods, and objectives of the Physical Science Study Committee physics program for secondary schools and to analyze their effectiveness in teaching physics to students enrolled in a selected group of small high schools in Texas.[37]

The study was conducted from September 1, 1963, to February 21, 1964. Seven high schools which met the following criteria participated. The school had to (1) have an experienced PSSC teacher to teach the course; (2) be a public school in Texas;

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[36]Robert W. Heath, "Comparison of Achievement in Two Physics Courses," _Journal of Experimental Education_, XXII (Summer, 1964), 347-350.

[37]Paul Jackson Cowan, "Development of New Autoinstructional Materials and an Analysis of Their Effectiveness in Teaching Modern Physics in the Small High School," _Dissertation Abstracts_, XXV (November, 1964), 2879-2880.

(3) have an enrollment of one hundred or more. There were forty-eight students in the control group and twenty-two students in the experimental group. Volunteers were used.

Pre-test results indicated that the mean IQ of the control group was significantly higher, but there was no difference in science background and reading ability. The conclusion was reached that there was no significant difference between the control and experimental methods in the effectiveness of teaching physics to high school students.[38]

In his research Dale Donald Rathe's purpose was to identify and state the subject matter in general physics which appeared preliminary to and basic for those who took the PSSC physics course. He asked the opinions of PSSC high school physics instructors concerning desirability of students attaining certain general physics principles prior to taking the PSSC physics course.

Two hundred twenty-three general principles were submitted to twenty-one high school physics teachers, who were teaching the PSSC course. The conclusion was reached that one hundred thirty-four of the general principles were needed

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[38] Ibid.

prior to taking the PSSC course.[39]

In his November 28, 1964, address to the Central Association of Science and Math Teachers, Ralph A. Sawyer, Acting Director of the American Institute of Physics at the University of Michigan, said he felt that traditional physics had not kept pace with the times and that the new (PSSC) method's emphasis on experimentation and discovery was "the method of the scientist."[40] He noted that there was a need for "science literacy."[41]

In his dissertation "The Attainment of the Concept 'Understanding Science' Using Contrasting Physics Courses," John Harvey Trent compared the relative effectiveness of the traditional high school physics course and the physics curriculum developed by the Physical Science Study Committee in attaining the objective of understanding Science. The null hypothesis,

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[39]Dale Donald Rathe, "Certain Physics Generalizations Desirable for Students to Attain Before Taking the Physical Science Study Committee's High School Course," _Dissertation Abstracts_, XXV (December, 1964), 3330.

[40]Ralph A. Sawyer, "Reflections on the High School Curriculum," _School Science and Mathematics_, LXV (May, 1965), 389.

[41]_Ibid._, p. 400.

> when the variables of prior science understanding and mental ability are statistically controlled, there is no difference between the control group [traditional physics students] and the experimental group [PSSC physics students] in mean scores of understanding science as measured by the Test on Understanding Science.[42]

was used. The term "understanding science" meant understanding

> the development of science and the scientific enterprise, the structure and methods of science, and science as a product of human intelligence as measured by the Test on Understanding Science.[43]

The traditional course had to meet the criteria of (1) being taught in the junior or senior year of high school, (2) including units on sound and heat, (3) being a college preparatory course, (4) not using the PSSC text. The control group consisted of twenty-six California high schools, randomly selected, at which the traditional physics course was taught. The experimental group consisted of twenty-six California high schools, teaching PSSC physics, chosen at random.

The Otis Quick-Scoring Mental Ability test was given during the first two weeks of the 1963-64 school year. At the

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[42]John Henry Trent, "The Attainment of the Concept 'Understanding Science' Using Contrasting Physics Courses," Dissertation Abstracts, XXVI (July, 1965), 161.

[43]Ibid.

same time students in thirteen high schools in each group were given the Test on Understanding Science. During the last three weeks of the 1963-64 school year, all of the students were given the Test on Understanding Science. The school mean was used as the sampling unit in all data analysis. Analysis of variance showed no difference between the pre-tested and unpre-tested groups implying no effect due to pre-testing. The experimental group scored significantly higher at the .01 level on the Test on Understanding Science. However, an analysis of covariance between the Otis Quick-Scoring Mental Ability test and the Test on Understanding Science showed no significant difference in the adjusted means on the Test on Understanding Science. The variability in school size and the unweighted school means used made a two by two factorial analysis of covariance necessary. The results of this analysis showed that there was no significant difference due to course or school size, or both interacting. The conclusion was reached that both courses were equally effective.[44]

In his dissertation "A Study of Understanding Science Developed in High School Physics," Glen Howard Crumb's

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[44]*Ibid.*, p. 162.

purpose was (1) to determine any significant difference in understanding science between students who took the PSSC course and students who took the traditional high school physics course, (2) to investigate methods of teachers whose classes showed the highest and lowest mean gain in understanding science.

The study group consisted of twelve hundred seventy-five students in twenty-nine high schools in Iowa, Kansas, Missouri, and Nebraska. The group was divided into four subgroups:

1. Subgroup PP -- students in a PSSC physics course with a teacher who had been trained to teach the PSSC course;
2. Subgroup PT -- students in a PSSC physics course with a teacher who had not been trained to teach the PSSC course;
3. Subgroup TP -- students in a traditional high school physics course with a teacher who had been trained to teach the PSSC course;
4. Subgroup TT -- students in a traditional high school physics course with a teacher who had not been trained to teach the PSSC course.

The Test on Understanding Science was used as the criteria measure. The students were pre-tested for mental ability and background in science. Analysis of variance, with analysis of covariance used for adjustments, was used to compare ability, background in science, and pre-test scores. The findings were:

1. significant gains at the .01 level were made by the entire population over the entire school year in understanding science;
2. the same was true for each semester;
3. for the entire school year very significant gains were made by the PP, TP, and TT subgroups; significant gains at the .05 level were made by the PT subgroup;
4. for the first semester only the PP subgroup made very significant gains; the TP and TT subgroups made significant gains; the PT subgroup did not show a gain at the .05 level over this period;
5. for the second semester only significant gains at the .05 level were made by the TP and TT subgroups; over this period, there was no significant gains for the PP or PT subgroups;
6. a very significant difference was found between the criterion test mean of the experimental group and that

of the control group each time the test for criterion was administered; the post-test mean of the group studying traditional physics was not significantly large so as to equal the pre-test mean of the group studying PSSC physics.[45]

The purpose of Elmer Thomas Hinkel's dissertation was "to determine the effect that the instruction in two undergraduate courses in general physics has upon critical thinking abilities in students."[46] The population consisted of students enrolled in two sophomore level physics courses at the University of Toledo. The experimental group studied physics by a method similar to the PSSC method. The two control groups (one afternoon and one evening class) studied physics in the traditional manner. The groups were chosen by non-ordered selection.

The study was conducted over a five month period. A questionnaire was used to obtain educational background and

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[45]Glen Howard Crumb, "A Study of Understanding Science Developed in High School Physics," Dissertation Abstracts, XXVI (September, 1965), 1506-1507.

[46]Elmer Thomas Hinkel, "A Study of Changes in Critical Thinking Ability as a Result of Instruction in Physics," Dissertation Abstracts, XXVI (March, 1966), 5291.

personal data. The students were pre-tested and post-tested for aptitude and achievement in physics. Analysis of variance and a _t_-test of the means were used. It was found that the experimental and control groups were similar in aptitude and previous science training. The following conclusions were reached:

1. all students increased in ability to think critically, but only the experimental group had significant growth;
2. the evening control group did worse than the other two groups in developing critical thinking ability;
3. students with prior training in physics showed a greater amount of growth in critical thinking ability;
4. it was not conclusive if the experimental or the traditional method was better in producing critical thinking ability;
5. all students had a significant amount of growth in physics as measured by the traditional physics aptitude test;
6. the day control group was the only group with significant growth in achievement as measured by the traditional physics achievement test;
7. students who had no prior physics training had a

greater amount of growth in aptitude and achievement;

8. there was no significant correlation between critical thinking and aptitude and achievement scores.[47]

A review of the literature shows there has been research comparing traditional high school physics and PSSC high school physics in objectives, critical thinking ability, and "understanding science," but there has been no research with the express purpose of comparing the understanding of basic principles of physics as taught by the two courses. That was the purpose of this study.

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[47] Ibid.

CHAPTER III

RESEARCH PROCEDURES

I. SELECTION OF THE INSTRUMENT

The Cooperative Science Test in Physics was used as a measure of the ability to understand the basic principles of physics. In a review of an older form of the test, the reviewer found "little criticism"[48] of the content with the exception of not enough questions on the subject of modern physics. This study used a newer form of the test which contained more questions dealing with the area of modern physics. The reviewer found, in general, that the test items were carefully constructed and that the test as a whole was a "commendable piece of work."[49] The reviewer also stated that "many of the interpretive items are thought provoking, and the problems require for their solution more than just

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[48]Oscar Krisen Buros, The Fifth Mental Measurements Yearbook (Highland Park, New Jersey: Gryphon Press, 1953), p. 751.

[49]*Ibid*.

the mere substitution of numbers into memorized equations."[50] The Cooperative Science Test in Physics was chosen because of its high rating as a test of understanding in conventional physics and because the nature of the test items made it a suitable measure of understanding in PSSC physics.

II. COLLECTION OF THE DATA

In September 1967, Form A of the Cooperative Science Test in Physics was administered to the students enrolled in physics at Grimsley and Page High Schools as a pre-test in the ability to understand physics. Form B of the Cooperative Science Test in Physics was administered in February 1968 to the same students as a post-test in the ability to understand the basic principles of physics.

III. ANALYSIS OF THE DATA

The test results between the E and C groups were compared by means of analysis of covariance. These results are contained in Tables I and II, pages 41-43. Analysis of covariance was used in order to hold constant any

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[50] Ibid.

initial differences between the two groups. Table III, pages 45-46, contains the computations involved in this analysis.

CHAPTER IV

RESULTS OF THE STUDY

Table I, page 41, contains the results of the tests administered to the control group. Table II, pages 42-43, contains the test results for the experimental group. Tables I and II are constructed as follows:

1. the first column contains the pre-test scores, denoted by X;
2. the second column contains the pre-test scores squared, X^2;
3. the third column contains the post-test scores, denoted by Y;
4. column four is the post-test scores squared, Y^2;
5. column five contains the pre-test scores multiplied by the corresponding post-test score for each individual, XY;
6. the sixth column contains the individual's post-test score minus his pre-test score, denoted by D;
7. column seven is the square of the difference in the individual's post-test and pre-test score, D^2.

TABLE I

TEST DATA FOR THE CONTROL GROUP
(PAGE HIGH SCHOOL)

Pre-test scores X	X^2	Post-test scores Y	Y^2	XY	Difference D	D^2
33	1089	47	2209	1551	14	196
68	4624	82	6724	5576	14	196
41	1681	63	3969	2583	22	484
35	1225	56	3136	1960	21	441
66	4356	92	8464	6072	26	676
30	900	55	3025	1650	25	625
38	1444	35	1225	1330	- 3	9
40	1600	59	3481	2360	19	361
32	1024	50	2500	1600	18	324
53	2809	73	5329	3869	30	900
29	841	42	1764	1218	13	169
25	625	45	2025	1125	20	400
51	2601	68	4624	3468	17	289
40	1600	57	3249	2280	17	289
35	1225	51	2601	1785	16	256
35	1225	64	4096	2240	29	841
63	3969	68	4624	4284	5	25
40	1600	63	3969	2520	23	529
23	529	36	1296	828	13	169
34	1156	51	2601	1734	17	289
54	2916	53	2809	2862	- 1	1
33	1089	54	2916	1782	21	441
23	529	41	1681	943	18	324
921	40657	1305	78317	55620	384	7734

TABLE II

TEST DATA FOR THE EXPERIMENTAL GROUP
(GRIMSLEY HIGH SCHOOL)

Pre-test scores X	X^2	Post-test scores Y	Y^2	XY	Difference D	D^2
45	2025	45	2025	2025	0	0
42	1764	58	3364	2436	16	256
54	2916	64	4096	3456	10	100
40	1600	52	2704	2080	12	144
49	2401	96	9216	4704	47	2209
49	2401	59	3481	2891	10	100
55	3025	71	5041	3905	16	256
64	4096	91	8281	5824	27	729
77	5929	91	8281	7007	14	196
38	1444	77	5929	2926	39	1521
49	2401	79	6241	3871	30	900
47	2209	59	3481	2773	12	144
49	2401	67	4489	3283	18	324
38	1444	49	2401	1862	11	121
42	1764	71	5041	2982	29	841
24	576	48	2304	1152	24	576
30	900	48	2304	1440	18	324
35	1225	55	3025	1925	20	400
89	7921	102	10404	9078	13	169
29	841	64	4096	1856	35	1225
61	3721	93	8649	5673	32	1024
45	2025	59	3481	2655	14	196
49	2401	44	1936	2156	- 5	25
46	2116	54	2916	2484	8	64
49	2401	60	3600	2940	11	121
44	1936	53	2809	2332	9	81

TABLE II
(CONTINUED)

Pre-test scores X	X^2	Post-test scores Y	Y^2	XY	Difference D	D^2
38	1444	52	2704	1976	14	196
39	1521	41	1681	1599	2	4
59	3481	88	7744	5192	29	841
62	3844	77	5929	4774	15	225
71	5041	100	10000	7100	29	841
29	841	50	2500	1450	21	441
37	1369	45	2025	1665	8	64
50	2500	68	4624	3400	18	324
40	1600	55	3025	2200	15	225
34	1156	61	3721	2074	27	729
53	2809	72	5184	3816	19	361
54	2916	75	5625	4050	21	441
49	2401	53	2809	2597	4	16
56	3136	76	5776	4256	20	400
53	2809	57	3249	3021	4	16
34	1156	55	3025	1870	21	441
54	2916	71	5041	3834	17	289
48	2304	65	4225	3120	17	289
61	3721	89	7921	5429	28	784
2160	110848	2959	206403	149139	799	18973

Analysis of covariance was used to compare the change in performance from pre- to post-test between the two groups. Table III, pages 45-46, contains the mathematical work involved in this analysis. The analysis showed no significant difference; therefore, the null hypothesis was accepted. There could be two possible reasons for this result: (1) neither group made significant improvement; (2) both groups made comparable improvement. In order to test these possibilities a _t_-test was used to compare the means of the pre-test and post-test scores for each group. Table IV, page 47, contains the mathematical work for the _t_-test of the control group based on the data in Table I, page 41. The pre-test mean, $\bar{X}$, for this group is 40.04. The post-test mean, $\bar{Y}$, is 56.74. "D" is the difference between these two scores. There are twenty-two degrees of freedom for this group. The _t_ ratio 10.31 shows significant improvement at the .01 level of confidence.

Table V, page 48, contains the mathematical work for the _t_-test of the experimental group based on the data in Table II, pages 42-43. The pre-test mean, $\bar{X}$, for the experimental group is 48.00. The post-test mean, $\bar{Y}$, is 65.76. There are forty-four degrees of freedom for this group. The difference in the pre- and post-test mean is 17.76. The

TABLE III

ANALYSIS OF COVARIANCE

Control Group N = 23

Experimental Group N = 45

Correction (X) = $(X)^2/N = (3081)^2/68 = 139596.49$

Correction (Y) = $(Y)^2/N = (4264)^2/68 = 267377.88$

Correction (XY) = $(X)(Y)/N = (3081)(4264)/68 = 193196.82$

SS (total X) = $X^2 - c_x = 151505.00 - 139596.49 = 11908.51$

SS (total Y) = $Y^2 - c_y = 284720.00 - 267377.88 = 17342.12$

SS (total XY) = $XY - c_{xy} = 204759.00 - 193196.82 = 11562.18$

SS (between X) = $(X_c)^2/N_c + (X_e)^2/N_e - c_x$

$= (921)^2/23 + (2160)^2/45 - c_x = 963.55$

SS (between Y) = $(Y_c)^2/N_c + (Y_e)^2/N_e - c_y$

$= (1305)^2/23 + (2959)^2/45 - 267377.88 = 1237.38$

SS (between XY) = $(X_c)(Y_c)/N_c + (X_e)(Y_e)/N_e - c_{xy}$

$= (921)(1305)/23 + (2160)(2959)/45 - 193196.82$

$= 1091.91$

TABLE III
(CONTINUED)

total $SS_{yx} = SS_y - (SS_{xy})^2/SS_x$

$= 17342.12 - (11562.18)^2/11908.51 = 6116.28$

within $SS_{yx} = SS_y - (SS_{xy})^2/SS_x$

$= 16104.74 - (10470.27)^2/10944.96 = 6088.67$

Source	df	SS_x	SS_y	MS_x	MS_y
Between	1	963.55	1237.38	963.55	1237.38
Within	66	10944.96	16104.74	165.83	244.01
Total	67	11908.51	17342.12		

3.99 = .05 level

1/66 F_x = (963.55)/(165.83) = 5.81

7.04 = .01 level

1/66 F_y = (1237.38)/(244.01) = 5.07 significant at .05 level

Source	df	SS_x	SS_y	SS_{xy}	SS_{yx}	MS_{yx}	SD_y
Between	1	963.55	1237.38	1091.01	27.61	27.61	
Within	65	10944.96	10944.96	10470.27	6088.67	93.67	9.68
Total	66	11908.51	11908.51	11562.18	6116.28		

1/65 F = (27.61)/(93.67) = 0.029 not significant

TABLE IV

t-TEST FOR THE CONTROL GROUP

$$\Sigma d^2 = \Sigma D^2 - (\Sigma D)^2/N = 7734 - (384)^2/23$$

$$\Sigma d^2 = 1322.87$$

$$\sigma_d = \sqrt{\Sigma d^2/N} = \sqrt{1322.87/23} = 7.58$$

$$\sigma_{diff} = \frac{\sigma_d}{\sqrt{N-1}} = \frac{7.58}{\sqrt{22}} = 1.62$$

$\bar{X} = 40.04$ $\bar{Y} = 56.74$

$$D = \bar{Y} - \bar{X} = 56.74 - 40.04 = 16.70$$

$$t = \frac{D}{\sigma_{diff}} = \frac{16.70}{1.62} = 10.31$$

$df = 22$

Significant at the .01 level of confidence

TABLE V

$\underline{t}$-TEST FOR THE EXPERIMENTAL GROUP

$$\Sigma d^2 = \Sigma D^2 - (\Sigma D)^2/N = 18973 - (799)^2/45$$

$$\Sigma d^2 = 4786.3$$

$$\sigma_d = \sqrt{\Sigma d^2/N} = \sqrt{4786.3/45} = 10.31$$

$$\sigma_{diff} = \frac{\sigma_d}{\sqrt{N-1}} = \frac{10.31}{6.63} = 1.56$$

$$\bar{X} = 48.00 \qquad \bar{Y} = 65.76$$

$$D = \bar{Y} - \bar{X} = 65.76 - 48.00 = 17.76$$

$$t = \frac{D}{\sigma_{diff}} = \frac{17.76}{1.56} = 11.38$$

$$df = 44$$

Significant at the .01 level of confidence

t ratio is 11.38 which is significant at the .01 level of confidence.

Since each group made improvement at the .01 level of confidence, it was concluded that both groups made comparable improvement. Again it should be noted that the results of this study are confined to the limitations previously stated.

CHAPTER V

SUMMARY AND CONCLUSIONS

I. SUMMARY

The review of the literature shows that there has been research comparing traditional high school physics and PSSC high school physics in objectives, critical thinking ability, and "understanding science." All of these studies have found the two courses to be comparable. The PSSC physics course has been praised for its

1. fresh approach to teaching physics using up-to-date material;
2. excellent films;
3. excellent laboratory program;
4. suitability for the student who does not have an extensive mathematical background.

The PSSC course has the following disadvantages:

1. some prior understanding of the general principles of physics may be necessary before taking the PSSC course;
2. special training is desirable for a teacher before teaching the PSSC course;
3. the PSSC course is aimed at the more able student;
4. there is little emphasis on mathematics.

II. CONCLUSIONS

This study compared PSSC physics and traditional physics in the area of understanding of the basic principles of physics. The following conclusions were reached:

1. There was no significant difference between the two courses in this area.
2. Both courses are teaching physics effectively.
3. The learning outcome from the two courses is comparable.

Judging from the results of this study and a review of the literature, after considering the training of its teachers and the economic feasibility of each course, the school system should be able to choose either the PSSC course or the traditional course without having to fear that perhaps it is not offering its students the best course available.

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APPENDIXES

APPENDIX A

STATISTICAL SUMMARY FROM "COMPARISON OF ACHIEVEMENT IN TWO PHYSICS COURSES," BY ROBERT W. HEATH[51]

Test	PSSC group (N=30) mean score	SD	Control group (N=49) mean score	SD
SCAT	42.7	3.4	39.3	4.3
Cooperative Physics	39.7	7.7	41.4	6.4
PSSC Final	29.5	5.4	18.7	4.0
Concealed Figures	61.8	6.0	52.4	7.7

Correlation Matrices	PSSC group, N=30			Non-PSSC group, N=49		
	(1)	(2)	(3)	(1)	(2)	(3)
(1) SCAT						
(2) Cooperative Physics	.5			.77		
(3) PSSC Final	.73	.78		.23	.34	
(4) Concealed Figures	.41	.60	.55	.42	.37	.01

Analysis of Covariance

source of variation	df	2	mean squared	adjusted cooperative means
within	76	215603	2837	PSSC=37.4
between	1	47975	47975	non-PSSC=42.8
total	77	263578		

F=16.9 significant at .01 level

[51]Heath, p. 350.

APPENDIX B

STRATIFICATION OF CLASSES[52]

	100,000 or Greater Population		Fewer than 100,000 Population		
	Male	Female	Male	Female	Total
East	----- -----	PSSC 1 -----	PSSC 8 Non-PSSC 10	PSSC 1 Non-PSSC 4	PSSC 10 Non-PSSC 14
Mid-West	----- Non-PSSC 1 (traditional)	PSSC 1 -----	PSSC 6 Non-PSSC 12	PSSC 1 Non-PSSC 2	PSSC 8 Non-PSSC 15
South	PSSC 2 -----	PSSC 1 -----	PSSC 3 Non-PSSC 6	PSSC 1 Non-PSSC 3	PSSC 7 Non-PSSC 9
West	PSSC 2 Non-PSSC 1	----- -----	PSSC 2 Non-PSSC 9	PSSC 1 Non-PSSC 1	PSSC 5 Non-PSSC 11
Totals	PSSC 4 Non-PSSC 2	PSSC 3 Non-PSSC 0	PSSC 19 Non-PSSC 37	PSSC 4 Non-PSSC 10	PSSC 30 Non-PSSC 49
	PSSC 7 Non-PSSC 2		PSSC 23 Non-PSSC 47		

[52] *Ibid.*, p. 351.